ARCNET Local Area Network Standard

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Direct comments and questions to:

ATA Standards Committee

c/o ARCNET Trade Association

Table of Contents

1. Introduction

1.1 Scope

For the purpose of compatible interconnection of information processing equipment via the ARCNET token bus local area network, this standard:

(1) Defines the frame formats, (see Section 3);
(2) Defines the medium access control protocol in terms of finite-state machines (see Section 4);
(3) Defines service primitives and parameters for use at the conceptual interfaces between the medium access control sublayer and the logical link control sublayer, and between the medium access control sublayer and the physical layer (see Section 5);
(4) Defines the physical layer functions (see Section 6);
(5) Defines the medium interface connector for attachment of the physical medium to each station and the electrical characteristics of the signaling method (see Section 7);

and

(6) Defines the operation of an active hub (see section 8).

The primary emphasis of this standard is to specify the homogeneous, externally visible characteristics needed for interconnection compatibility, while avoiding unnecessary constraints upon and changes to internal design and implementation of the heterogeneous processing equipment to be interconnected.

A particular constraint in the development of this standard is to specify the operation of ARCNET in such a manner that future implementations conforming to this standard shall be fully interoperable with the existing population of ARCNET stations, which numbered over 2 million at the time work on this standard was begun.

1.2 Compliance Levels

There are several sets of facilities described in this standard.

(1) A set of basic facilities which all ARCNET stations must implement;
(2) A series of optional facilities which may be implemented on a facility-by-facility basis, and must conform to this standard if implemented; and
(3) Several media interface and topology alternatives.

1.2.1 Basic Facilities

The set of basic facilities provides for communication among all ARCNET stations. Implementation of the complete set of basic facilities is mandatory for all ARCNET stations. All portions of this standard are part of the basic facility set unless specifically designated as "optional".

1.2.2 Optional Facilities

The only optional facility is three levels of extended timeouts, which permit operation over longer interconnection paths.

1.2.3 Media Interface and Topology Alternatives

The media interface alternatives include:

(1) coaxial cable media, connected via a BNC connector; and
(2) twisted pair media, connected via an RJ11 connector.

The media topology alternatives include:

(1) star topology, in which each media segment is a point-to-point connection between a station and a wiring concentrator (hub); and
(2) bus topology, in which media segments may be multi-drop connections with a plurality of stations attached along the path.

1.2.4 Compliance Nomenclature

The portions of this standard with which each ARCNET-related product complies shall be identified in the following manner:

(1) "ARCNET" indicates compliance with this standard for the basic facility set;
(2) "-X" following ARCNET indicates support for all three levels of extended timeouts (if any extended timeouts are supported, all must be supported);
(3) "/C" following ARCNET indicates the use of a media interface connector for coaxial cable;
(4) "/T" following ARCNET indicates the use of a media interface connector for twisted pair cable;
(5) "/S" following ARCNET indicates support for star topology; and
(6) "/B" following ARCNET indicates support for bus topology.

Examples:

"ARCNET-X/CS"	indicates support for basic ARCNET with extended timeouts, for use on star-wired, coaxial media.
"ARCNET/TB"	indicates support for basic ARCNET, for use on bus-wired, twisted pair media.
"ARCNET-X/CTBS"	indicates support for basic ARCNET with extended timeouts, for use on either star or bus wiring with either coaxial or twisted pair media.

1.3 Terminology and Notation

This section defines some of the abbreviations, definitions of internal terminology, and numeric and state machine notation used in this document.

1.3.1 Acronyms

ARCNET	Attached Resource Computer NETWORK
AB	Alert Burst
ACK	ACKnowledgement
BE	Broadcast Enabled flag
CP	Continuation Pointer
CRC	Cyclic Redundancy Check
DID	Destination (station) IDentifier
FBE	Free Buffer Enquiry
FCS	Frame Check Sequence
FF	Fbe detected Flag
FID	Frame (type) IDentifier
FR_BAD	FRame BAD, invalid
FSM	Finite State Machine
ID	IDentifier
IF	Itt detected Flag
IL	Information (field) Length
INFO	INFOrmation (field)
ISU	Information Symbol Unit
ITT	Invitation To Transmit
LLC	Logical Link Control
MAC	Medium Access Control
MIC	Medium Interface Connector
MYID	MY (station) IDentifier
NAK	Negative AcKnowledgement
NID	Next (station) IDentifier
NMT	Network ManagementT
PAC	data PACket
PDU	Protocol Data Unit
PF	Pac detected Flag
PHY	PHYsical
POR	Power On Reset
RECON	network RECONfiguration
RI	Receiver Inhibited
RSU	Reconfiguration Symbol Unit
RXD	Receiver Destination identifier
SC	System Code
SD	Starting Delimiter
SID	Source (station) IDentifier
SDU	Service Data Unit
TA	Transmitter Available
TAC	Timer, ACtivity time-out
TBR	Timer, BRoadcast delay
THU	Timer, Hub Unlatch delay
TIP	Timer, Identifier Precedence
TLT	Timer, Lost Token
TMA	Transmitter Message Acknowledged
TMQ	Timer, Medium Quiescent
TRB	Timer, Receiver Blanking
TRC	Timer, ReCovery
TRP	Timer, ResPonse time-out

TTA Timer, Turn Around
TXD Transmitter Destination identifier

1.3.2 Definitions

activity (or network activity)
(ARCNET-specific definition) A condition where the receiver at a station detects symbols representing binary ones with a predefined minimum periodicity.

address
A value used to identify a station. Addresses must be unique within any set of stations connected to a single network.

broadcast transmission
A transmission addressed such that it is received by all stations.

data packet
(ARCNET-specific definition) A frame which conveys arbitrary information supplied by an LLC (or higher level) entity between stations.

frame
A transmission unit that carries a physical PDU on the medium.

framing bits
(ARCNET-specific definition) The three non-information symbols which precede the information bits in an ISU.

frame check sequence (FCS)
The portion of a frame which contains error-detection code values for checking the information in that frame.

logical link control (LLC)
That part of the data link layer that supports media independent data link functions and uses the services of the medium access control sublayer to provide services to the network layer.

medium
The material on which the data may be transferred between stations. Twisted pair cable, coaxial cable, and optical fibers are each examples of media.

medium access control (MAC)
The portion of the ARCNET station that controls and mediates access to the medium.

MAC frame
A frame which is used to communicate between MAC entities for the purpose of controlling access to and/or communication over the medium.

medium interface connector (MIC)
The connector between the station and the medium through which all transmitted and received signals are specified.

network management (NMT)
The conceptual control element of a station which interfaces with all of the layers of the station and is responsible for the setting and re-setting of control parameters, obtaining reports of error conditions, and determining if the station should be connected or disconnected from the medium.

physical (PHY) layer
The layer responsible for interfacing with the medium, detecting and generating signals on the medium, and converting and processing signals received from the medium and medium access control sublayer.

protocol data unit (PDU)
Information delivered as unit between peer entities which contains control information and, optionally, data.

repeater
A device used to extend the length, topology, or interconnectivity of the medium beyond that imposed by the limitations on a single segment of medium between stations and/or repeaters. *Repeaters* are often referred to as hubs.

service data unit (SDU)
Information delivered as a unit between adjacent entities which may also contain a PDU of the upper layer.

silence (on network)
(ARCNET-specific definition) A condition where the receiver at a station detects no symbols representing binary ones during a specified period of time.

starting delimiter (SD)
The fixed pattern of symbols which is transmitted at the beginning of each frame and may be used to uniquely identify the beginning of that frame.

station
A physical device that may be attached to a shared medium local area network for the purpose of transmitting and receiving information on that shared medium. A station is identified by its network address.

symbol
A single signal element on the medium, which typically represents one bit, but may represent more than one bit under certain modulation and/or encoding schemes.

symbol unit
A fixed-size group of symbols used for a particular purpose within a PDU.

time-out
The expiration of the predetermined interval measured by a timer.

token
The symbol of authority that is passed between stations using a token access method to indicate which station is currently in control of the medium.

token loop
The deterministic, orderly sequence of stations, often called the "logical ring", to which the token is passed during normal, steady-state network operation.

transmit
The action of a station placing a frame or reconfiguration burst on the medium.

1.3.3 Glossary of Traditional ARCNET Terminology

Prior to generation of this standard, typical ARCNET documentation used several terms which have been changed for standardization in order to bring them into closer agreement with conventional LAN standards terminology. The traditional ARCNET terms, along with the new terms, include:

ID = = > station address
Node = = > Station
Idle Timer = = > Activity Timer (TAC)
RECON Timer = = > Lost-Token Timer (TLT)
Alert Burst (AB) = = > Starting Delimiter (SD)
Continuation Pointer (CP) = = > Information Length (IL)
Cyclic Redundancy Check (CRC) = = > Frame Check Sequence (FCS)

1.3.4 Numbers

In this document, numerical constants are to be interpreted as decimal values unless preceded by a "0x" in which case they are in hexadecimal, or a "0b" in which case they are in binary.

All cardinal numeric values in this document are to be treated as unsigned integers unless otherwise specified. All ordinal numeric values in this document are to be treated as 0-origin unless otherwise specified.

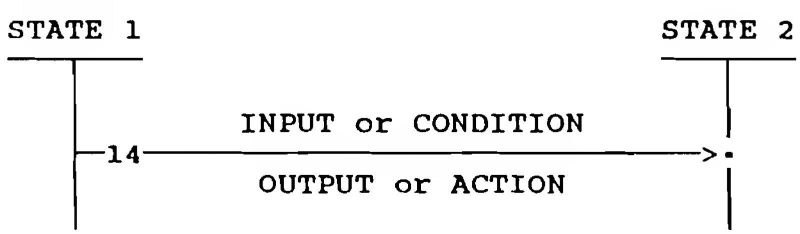
In all bit position numbering, bit zero represents the least-significant bit.

1.3.5 Times

In this document, time intervals are designated "ms" for milliseconds (10^{-3} second), "us" for microseconds (10^{-6} second), or "ns" for nanoseconds (10^{-9} second). If tolerances to specified time values are not listed, they may be assumed to be plus or minus 50% of one unit of the least significant digit shown.

1.3.6 Finite State Machines

The notation used in FSM diagrams is as follows:



States are shown as vertical lines. Transitions are shown as horizontal lines with a number indicating the transition (for example, 14) and the arrow indicating the direction of transition. The leading digit(s) of the transition number is the number of the state being exited.

The input or condition shown above the line is the requirement to make the transition. The output or action shown below the line occurs simultaneously with making the transition. The transition begins when the input occurs or the condition specified is met and is complete when the output or action has been completed. If the state transition is in progress, then no other FSM transition may be initiated.

If the exit conditions of a state are satisfied at the time the state is entered, no action is taken in that state and the state is immediately exited.

In the FSM diagrams the following notation is used:

Load(...)	Load the specified field from the transmitter buffer
Reset(...)	Reset the specified timer(s)
RX(...)	Detect reception of the indicated frame or symbol
RX(until ...)	Receive and ignore anything until the specified symbol is detected
TO(...)	Time Out of the indicated timer
TX(...)	Transmit the indicated frame
Set(...)	Set the specified flag(s)
Stop(...)	Stop the specified timer(s)
Store(...)	Store the specified fields from the frame being received into the receiver buffer
v	Logical inclusive-OR
&	Logical AND
~	Logical NOT
,	Actions separated by commas are performed concurrently
=	Compare for equal
!=	Compare for not equal
:=	Assign value on right to register on left
+	Arithmetic unsigned addition
mod	Arithmetic unsigned modulus

1.4 Acknowledgement

Many structural, editorial, and appearance aspects of this document, as well as certain terminology and notation (particularly the FSM notation) are patterned after ANSI/IEEE Standard 802.5-1985. The authors of this document wish to thank the 802.5 Working Group for having written what is among the most readable network standards ever generated.

2. General Description

This standard specifies the formats and protocols used by the ARCNET token passing bus medium access control (MAC) sublayer and physical (PHY) layer. The ARCNET model and its relationship to the Open Systems Interconnection (OSI) reference model of the International Organization for Standardization (ISO) is illustrated in Figure 2.1.

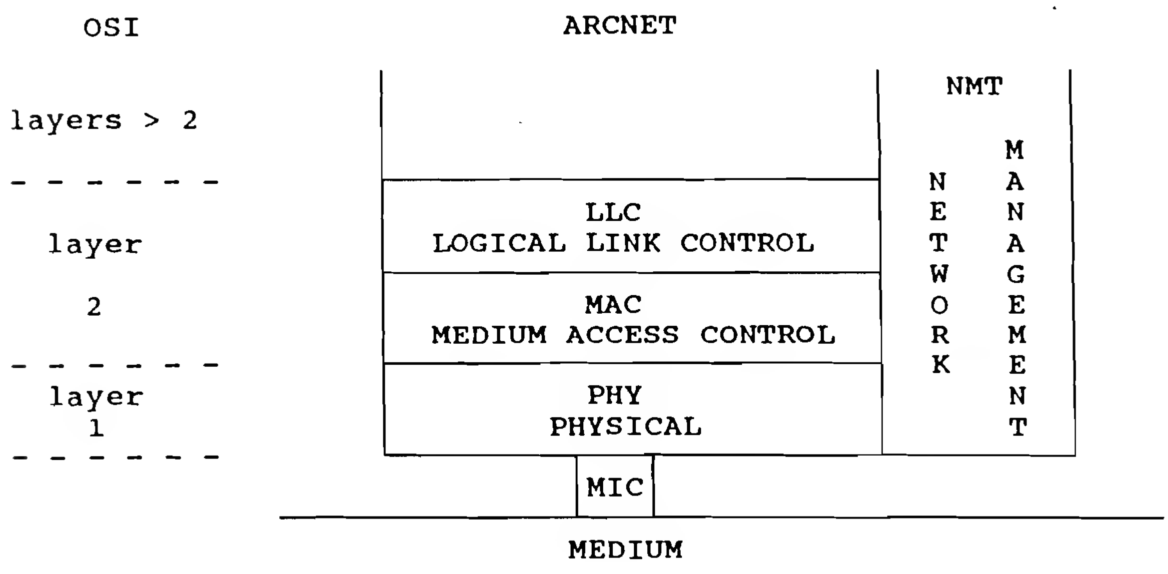


Figure 2.1
Relation of OSI Reference Model to ARCNET Model

2.1 Overview of ARCNET Capabilities

ARCNET provides
* reliable transfer of variable-size data packets among a plurality of stations,
* using a baseband signaling scheme which is capable of
* operating over any of a wide range of acceptable media.

Medium access control is accomplished through token passing, creating a logical ring on the physical bus. The bus structure permits use of a single interconnection conductor to each station. The media may be arranged using either a multi-centric star (also called an unrooted tree) structure or a multidrop bus structure for the physical interconnect topology.

2.1.1 Basic Capabilities

Basic ARCNET provides communication
(1) among up to 255 stations,
(2) at a rate of 2.5Mbps,
(3) over media with aggregate path delays of up to 31usec (using standard timeouts),
(4) with data packets containing up to 507 data bytes.

2.1.2 Optional Capabilities

The only optional capability is

three levels of extended timeouts, which permit network operation over substantially greater lengths of media.

2.2 ARCNET Fundamentals

On ARCNET, a token is used to designate the station which currently has control of the physical medium. The token is a control frame comprised of a unique signalling sequence which is transferred over the medium following each information transfer sequence. The station which holds the token has the exclusive right to transmit onto the medium. This right to transmit may be temporarily donated to another station, for use in acknowledging a transmission by the token holder. Within a specified time interval the token holder must relinquish control of the medium by passing the token to a predetermined other station.

The token is passed from station to station in a circular fashion, as if on a logical ring. This token passing pattern is referred to as the token loop. All active stations participate in the token loop. Maintenance of the token loop is implemented by functions within the stations providing for token loop initialization, lost token recovery, addition of new stations to the token loop, and reconfiguration when stations are removed from the token loop. Token loop maintenance functions are replicated among all the stations on the network.

ARCNET uses exclusively broadcast media. On a broadcast medium, all stations receive the signals transmitted by another station at approximately the same time. The creation of a logical ring for token passing on the physical bus is illustrated in Figure 2.2. In this diagram the token loop is denoted by a series of directional, dashed lines. Stations B, C, E, F, and G are participating in the token loop and are therefore able to perform information transfers over the medium. Stations A and D are inactive (typically powered off) and neither participate in, nor interfere with, the token loop and information transfers.

Note that the token medium access method always involves sequential token passing in a logical sense. That is, during normal, steady state operation, the right to access the medium passes from station to station in an orderly, predetermined, and consistent manner. Furthermore, note that the physical connectivity has no impact on the order of token passing within the token loop, and that stations can respond to a query from the token holder independent of their position on the token loop and independent of their position on the physical medium.

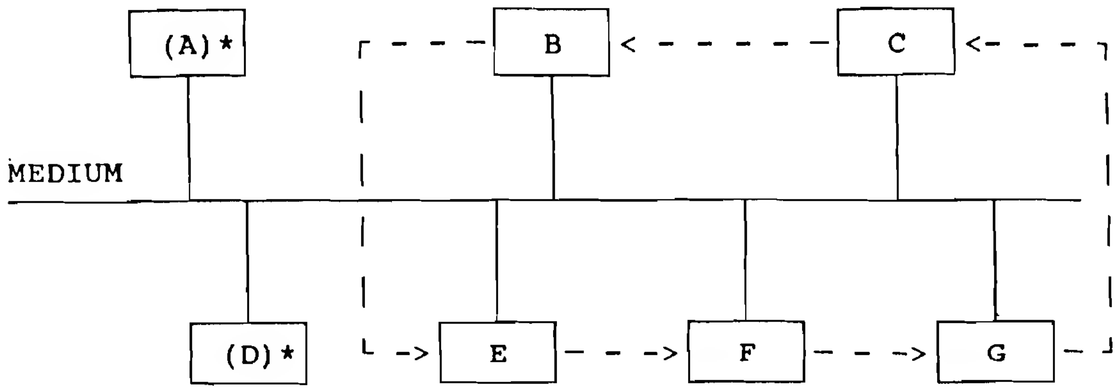


Figure 2.2
Logical Ring on Physical Bus

* - Stations A & D are inactive

The Medium Access Control (MAC) sublayer provides sequential access to the shared bus medium by passing control of the medium from station to station in a logically circular fashion. The MAC sublayer determines when the station has the right to access the shared medium by recognizing and accepting the token from the predecessor station and determines when the token shall be passed to the successor station. Upon receipt of the token, a station may perform an inquiry phase and a data transfer phase, prior to relinquishing control of the medium by performing a token transfer phase. If a station receives the token when it has no information to transfer over the medium, that station immediately enters the token transfer phase.

The token loop is automatically configured upon network initialization, and reconfigured dynamically as stations enter and leave the network. The sequence of token passing is from the active station with the highest address to the active station with the lowest address, then sequentially to active stations with successively higher addresses. A network reconfiguration process is invoked whenever the token is lost, a previously active station leaves the network, or a new station becomes active on the network. This reconfiguration process involves each station determining the address of its successor station on the token loop by polling of sequentially ascending station addresses. Once the address of the successor station is determined, tokens are passed directly to that station without further polling until the next network reconfiguration. In cases where the token has been lost or a new station has become active on the network, any existing network activity is forced to halt and the reconfiguration process is initiated. A time-out procedure, based on station address, is used to select the active station with the highest address for the purpose of starting the token loop (re-)initialization.

2.3 MAC Sublayer

The general functions of the MAC sublayer include:

(1) distributed initialization,
(2) lost token detection,
(3) station address recognition,
(4) frame encapsulation,
(5) FCS generation and checking,
(6) token generation and recognition,
(7) new station addition and deletion, and
(8) station failure error recovery.

2.4 PHY Layer

The general functions of the PHY layer include:

(1) generation of symbols on the medium which correspond to signals received from the MAC sublayer, and

(2) detection of symbols on the medium and processing of these symbols for delivery to the MAC sublayer.

2.4.1 Station Attachment

Stations are attached to the network media through specified Media Interface Connectors.

(1) For coaxial cable media, a BNC connector is used,

(2) for twisted pair cable media, an RJ11-C connector is used, and

(3) for optical fiber media, this standard does not specify a connector.

2.4.2 Topology Alternatives

Two media interconnect topologies are permitted -- star topology and bus topology.

(1) In star topology, each media segment is a point-to-point connection between a station and a wiring concentrator (commonly called a hub) or between a pair of wiring concentrators. The wiring concentrator repeats the incoming signal from any media segment onto all other attached media segments. The wiring concentrator may amplify or re-generate the physical signals, but does not buffer nor interpret these signals. Star topology is applicable to all permitted media types.

(2) In bus topology, each media segment may have a plurality of stations connected along the segment. An electrical terminator is required at each end of each segment, and may be supplied by a connection to a wiring concentrator to permit mixing of bus and star topology segments on a single network. Bus topology is only applicable to electrical cable media.

2.5 Media

Precise definition of suitable media, including twisted pair, coaxial, and optical fiber cables for connecting stations is not included in this standard. The specifications in Section 7 define the performance bounds to which an operating network, including the media and any repeaters or hubs, shall conform.

3. Formats And Facilities

3.1 Formats

There are two formats used on basic ARCNET:
(1) basic frames and
(2) reconfiguration bursts.

In the following discussion, the figures depict the formats of the fields in the sequence they are transmitted on the medium, with the least-significant bit (shown at the left of each figure) transmitted first.

3.1.1 Basic Frame Format

SD	FID	FIS

SD = Starting Delimiter (6 basic symbols)

FID= Frame Identifier (1 ISU)

FIS = Frame Information Sequence (0-515 ISUs)

Basic frames are the means by which all control and information transfer functions occur between stations.

3.1.2 Reconfiguration Burst Format

RSU	RSU	RSU	. . .

RSU = Recon. Symbol Unit
(9 basic symbols)
(total of 765 RSUs)

The Reconfiguration Burst (RB) is used to force network initialization by terminating all activity on the network. The RB is longer than any type of frame, and will therefore interfere with the next Invitation To Transmit (ITT) frame, thereby preventing any station from receiving the token and obtaining the right to transmit onto the medium.

The constant of 765 for the number of RSUs in the reconfiguration burst is only proper in conjunction with default timeouts. The correct length of the Reconfiguration Burst is 3060 RSUs with level 1 extended timeouts, 6120 RSUs with level 2 extended timeouts, and 12240 RSUs with level 3 extended timeouts. However, generation of these longer Reconfiguration Bursts when operating with extended timeouts is optional, because ARCNET implementations prior to this standard do not change their Reconfiguration Burst length with changes in the extended time-out level. Using a 765-RSU Reconfiguration Burst with extended timeouts does not prevent proper network operation, but can result in non-deterministic network reconfiguration times.

3.1.3 Idle Condition

When no station is transmitting, the medium is in the binary zero state (silence). The idle condition may be any duration, within the constraints of the Lost Token time-out (TLT) and/or Response time-out (TRP) timers.

All types of (valid) transmissions begin with a binary one. When any type of transmission is taking place, a binary one will occur not less than once out of every 11 basic symbols. Silence for 11 basic symbol times may be used to detect the lack of (current) transmission activity; however, longer time periods are required to detect the lack of any network activity, due to allowable response times within the MAC protocol.

3.1.4 Basic Symbol Units

Basic symbol units are the elements used to construct basic frames and reconfiguration bursts. All valid basic transmissions contain an integral number of basic symbol units.

3.1.4.1 Starting Delimiter (SD)

1 1 1 1 1 1

1 = binary one

Every basic frame is started with these six symbols.

NOTE: The Starting Delimiter is referred to as the "Alert Burst" in traditional ARCNET documentation.

3.1.4.2 Information Symbol Unit (ISU)

1 1 0 i0 i1 i2 i3 i4 i5 i6 i7

1 = binary one
0 = binary zero
i0-i7 = information bits

Each byte of information being transferred between stations is preceded by (at least) two binary ones and (exactly) one binary zero. Otherwise, the information transfer is not considered valid. The least significant bit of the information byte is transmitted first.

3.1.4.3 Reconfiguration Symbol Unit (RSU)

1 1 1 1 1 1 1 1 0

1 = binary one
0 = binary zero

Each element of a reconfiguration burst contains these nine symbols. No sequence of other (valid) symbol units is capable of producing the same bit pattern as two or more, sequential RSUs; however, it is possible for an adjacent pair of valid ISUs to produce a bit pattern equivalent to a single RSU.

3.1.5 Basic Frame Types

The following is a description of each type of basic frame used on ARCNET.

In order for any basic frame to be considered valid at a receiving station, the last field of the frame must be followed by at least 9 basic symbol times of idle line condition (silence). Detection of any activity by the receiving station during this 9-symbol-time interval causes the preceding frame to be ignored.

3.1.5.1 Invitation To Transmit (ITT)

SD	ITT	DID

SD = Starting Delimiter (6 basic symbols)
ITT = ITT Frame (1 ISU, value = 0x04)
DID = Destination Identifier (2 ISUs)

The ITT frame is the means by which the right to transmit (token) is passed from one station to another.

3.1.5.2 Free Buffer Enquiry (FBE)

SD	FBE	DID

SD = Starting Delimiter (6 basic symbols)
FBE = FBE Frame Identifier (1 ISU, value = 0x85)
DID = Destination Identifier (2 ISUs)

The FBE frame is used to determine if the receiver at the destination station is currently able to accept a data packet.

3.1.5.3 Data Packet (PAC)

	FCS Coverage						
SD	PAC	SID	DID	IL	SC	INFO	FCS

SD = Starting Delimiter (6 basic symbols)
PAC = PAC Frame Identifier (1 ISU, value = 0x01)
SID = Source Identifier (1 ISU)
DID = Destination Identifier (2 ISUs)
IL = Information Length (1-2 ISUs)
SC = System Code (1 ISU)
INFO = Information (0-507 ISUs)
FCS = Frame Check Sequence (2 ISUs)

The PAC frame is used to transfer messages to the destination station(s). PAC frames may or may not have an information (INFO) field.

3.1.5.4 Positive Acknowledgement (ACK)

SD	ACK

SD = Starting Delimiter
(6 basic symbols)
ACK = ACK Frame Identifier
(1 ISU, value =0x86)

ACK frames are used to acknowledge successful receipt of PAC frames and as affirmative responses to FBE frames.

3.1.5.5 Negative Acknowledgement (NAK)

SD	NAK

SD = Starting Delimiter
(6 basic symbols)
NAK = NAK Frame Identifier
(1 ISU, value = 0x15)

NAK frames are used as negative responses to FBE frames.

3.2 Basic Field Descriptions

The following is a detailed description of the individual fields used in the various types of basic frames defined above.

3.2.1 Frame Identifier (FID)

1 1 0 f0 f1 f2 f3 f4 f5 f6 f7

1 = binary one
0 = binary zero
f0-f7 = frame identifier

The FID field is used to uniquely indicate the type, therefore the format, of the frame. Valid frame type values (transmitted lsb first) are:

0x01 = PAC
0x04 = ITT
0x15 = NAK
0x85 = ACK
0x86 = FBE

If a receiver detects any value not shown above in the FID field, the frame is ignored.

3.2.2 Destination Identifier (DID)

1 1 0 a0 a1 a2 a3 a4 a5 a6 a7	1 1 0 a0 a1 a2 a3 a4 a5 a6 a7

1 = binary one
0 = binary zero
a0-a7 = destination station address

The DID field contains two copies of the destination station address. A station only accepts an incoming frame if both copies of the destination station address are identical and are either equal to the station's assigned address or are 0x00. The address value of 0x00 is used to identify broadcast frames which are to be received by all stations.

3.2.3 Source Identifier (SID)

1 1 0 a0 a1 a2 a3 a4 a5 a6 a7

1 = binary one
0 = binary zero
a0-a7 = source station address

The SID field contains the assigned address of the station transmitting the frame.

3.2.4 Information Field Length (IL)

Each PAC frame contains an IL field to indicate the number of ISUs in the INFO field of the frame. The IL field may be one or two ISUs in length, depending on the length of the INFO field.

NOTE: The IL field is referred to as the "Continuation Pointer" (CP) in traditional ARCNET documentation.

3.2.4.1 IL Field for INFO Fields containing 0 to 252 ISUs

1 1 0 n0 n1 n2 n3 n4 n5 n6 n7

1 = binary one
0 = binary zero
n0-n7 = (255-N)
N = INFO field length

3.2.4.2 IL for INFO Fields containing 256 to 507 ISUs

1 1 0 0 0 0 0 0 0 0 0	1 1 0 m0 m1 m2 m3 m4 m5 m6 m7

1 = binary one (mark)
0 = binary zero (space)
m0-m7 = (511-N)
N = INFO field length

NOTE: It is not permissible to send INFO fields with 253, 254, or 255 ISUs. Messages of these lengths must be extended to contain at least 256 ISUs to be transmitted validly.

3.2.5 System Code (SC)

1 1 0 s0 s1 s2 s3 s4 s5 s6 s7

1 = binary one
0 = binary zero
s0-s7 = system code value

The SC identifies the higher level protocol usage of the INFO field. Assigned system codes are listed in Appendix 9.

NOTE: The system code is described as merely a conventional practice in traditional ARCNET documentation. Usage of a system code in each PAC frame is mandatory for compliance with this standard.

3.2.6 Information Field (INFO)

1 1 0 d0 d1 d2 d3 d4 d5 d6 d7	. . .

1 = binary one
0 = binary zero
d0-d7 = data byte
(0 to 507 ISUs)

The INFO contains zero or more bytes that are intended for MAC, NMT, LLC, or higher level usage. The maximum length of this field is 507 bytes.

3.2.7 Frame Check Sequence (FCS)

1 1 0 b0 b1 b2 b3 b4 b5 b6 b7	1 1 0 c0 c1 c2 c3 c4 c5 c6 c7

1 = binary one
0 = binary zero
b0-b7 = first check byte (FCS bits 0-7)
c0-c7 = second check byte (FCS bits 8-15)

NOTE: The FCS field is referred to as the "Cyclic Redundancy Check" (CRC) field in traditional ARCNET documentation.

The FCS uses a 16-bit cyclic code based on the following standard generator polynomial of degree 16:

$$G(X) = X^{16} + X^{15} + X^{2} + 1$$

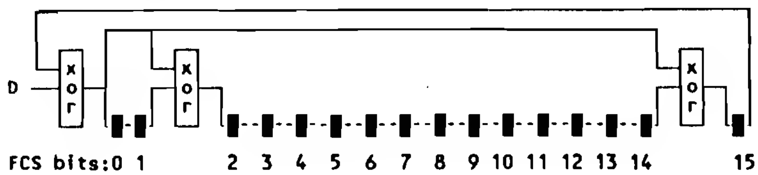
This discussion is provided strictly to clarify the FCS mechanism, and is not an indication of any mandatory implementation technique.

The FCS is generated using only the information bits from each ISU in the FID, SID, DID, IL, SC, and INFO fields of the frame.

The transmitter initializes the interim FCS value to zero prior to transmitting each frame, serially updates the interim FCS value based on each information bit of each ISU transmitted, and transmits the two check bytes based on the value of the FCS at the end of the IL field.

The receiver initializes the interim FCS value to zero prior to receiving each frame, serially updates the interim FCS value based on each information bit of each ISU received (including the ISUs containing the FCS), and checks the interim FCS value for being equal to zero after the last ISU of the frame has been received. If the resulting FCS value at the receiver is non-zero then the packet has been received in error and must be ignored.

The diagram below is a block diagram of the logic needed to implement the FCS generator/checker as a linear feedback shift register (LFSR). The "D" (data in) is the value of the information bit currently being transmitted or received. The LFSR is shifted one bit such that FCS bit 1 receives the value from FCS bit 0 on the active edge of the clock.



3.3 Timers

The timers defined below are used at each station to control various operational characteristics of the network. Several of these timer values are fixed, while several others are variable, and must be set to equal values at all stations on the network. The variable timer values are referred to in terms of "extended timeouts". Support for extended timeouts is optional, but if supported all extended time-out values must be selectable.

The term reset when applied to timers, is to be understood to mean that the timer is reset to its initial value and (re)started. When a timer's interval expires it is said to have "timed out", which asserts a time-out condition which remains true until the timer is reset. A timer may be stopped prior to time-out in order to prevent its time-out condition from occurring.

3.3.1 Timer, Lost Token (TLT)

Each station has a timer TLT to recover from error conditions related to non-receipt of the token. Timer TLT is reset each time the station receives the token, and is used to initiate network reconfiguration in cases where a time-out occurs before the next token reception. The operation of TLT is detailed in the operational finite-state machine. The default value of TLT is 840ms; the alternate value, for all levels of extended time-out, is 1680ms. The tolerance on both of these timer values is +/- 10ms.

TLT Timer	
Value	Tolerance
840ms	+/- 10ms

NOTE: This timer is referred to as the "RECON time-out" in traditional ARCNET documentation.

3.3.2 Timer, Identifier Precedence (TIP)

Each station has a timer TIP to provide time separation for initiation of network reconfiguration activity based on the station address. Operation of TIP is detailed in the operational finite-state machine. The value of TIP is determined (for default timeouts) by the station address according to the following equation:

$$\text{TIP value} = K * (255 - ID) + 3.0us$$

Value of K	
Timeout Level	Value
0 *	146us
1	584us
2	1168us
3	2336us

* - default value

The accuracy of this timer is +/- 5us.

3.3.3 Timer, Activity Timeout (TAC)

Each station has a timer TAC which is used to control the minimum period of time which the station will wait for media activity before assuming that such activity will not occur and commencing with network reconfiguration activity. Operation of the TAC is detailed in the operational finite-state machine.

Value of TAC		
Timeout Level	Minimum Value	Maximum Value
0 *	82.4us	87.6us
1	329.6us	350.4us
2	659.2us	700.8us
3	1318.4us	1401.6us

* - default value

NOTE: This timer is referred to as the "Idle time-out" in traditional ARCNET documentation.

3.3.4 Timer, Response Timeout (TRP)

Each station has a timer TRP which is used to control the minimum period of time which the station will wait for a response to a transmitted ITT, FBE, or PAC frame before assuming that such response will not occur. Operation of the TRP is detailed in the operational finite-state machine.

Value of TRP		
Timeout Level	Minimum Value	Maximum Value
0 *	75.6us	77.6us
1	302.4us	310.4us
2	604.8us	620.8us
3	1209.6us	1241.6us

* - default value

3.3.5 Timer, Recovery Time (TRC)

Each station has a timer TRC to provide time separation between the end of a response time-out and the start of a token pass. Operation of the TRC is detailed in the operational finite-state machine.

Value of TRC	
Value	Tolerance
2.0us	0.4us

3.3.6 Timer, Line Turnaround (TTA)

Each station has a timer TTA to control the minimum interval between the end of a received transmission and the start of a transmitted response. Operation of the TTA is detailed in the operational finite-state machine.

Value of TTA	
Minimum	Maximum
12.0us	13.6us

3.3.7 Timer, Medium Quiescent (TMQ)

Each station has a timer TMQ to control the sampling interval used to determine if a transmission is taking place on the medium. The lack of any detected one-bits during a TMQ period indicates a quiescent condition.

Value of TMQ	
Minimum	Maximum
4.0us	4.8us

3.3.8 Timer, Receiver Blanking (TRB)

Each station has a timer TRB to control the interval after the end of a transmission from this station that the receiver is to be blanked before valid network activity can be received.

Value of TRB	
Minimum	Maximum
5.6us	6.4us

3.3.9 Timer, Broadcast Delay (TBR)

Each station has a timer TBR to control the minimum interval between the end of a broadcast transmission and the start of a token pass. Operation of the TBR is detailed in the operational finite-state machine.

Value of TBR	
Minimum	Maximum
15.6us	20.0us

3.4 Flags

Flags are used to remember the occurrence of a particular event. They are set when the event occurs and are cleared as specified in the finite state machine definitions.

3.4.1 Receiver Inhibited (RI)

This flag is set upon successful receipt of a data packet addressed to this station, or a broadcast data packet, for which the reception and transfer to the station data buffer has been successfully completed and the frame check sequence verified. This flag is cleared by LLC functions when a empty buffer is available within the station data buffer and reception of data packets is again allowed. While this flag is set, no data packets are accepted by the station; however, invitation to transmit frames and free buffer enquiry frames, are accepted by the station at all times.

If an ARCNET implementation permits LLC functions to set this flag, logic must be included to ensure that it is not possible to change the state of RI during the reception of a data packet.

3.4.2 Transmitter Available (TA)

This flag is set upon completion of a data packet transmission attempt except in cases where a negative acknowledgement is received in response to a free buffer enquiry. This flag is cleared by LLC functions when a new data packet is available for transmission in the station's data buffer and packet transmission is to be performed on the next token reception. When this flag is set, this station passes the token immediately upon receipt, without attempting a transmission.

If an ARCNET implementation permits LLC functions to set this flag, logic must be included to ensure that it is not possible to change the state of TA during the transmission of a data packet.

3.4.3 Transmitter Message Acknowledged (TMA)

This flag is set coincident with TA in cases where the destination station has provided a positive acknowledgement to successful receipt of a data packet. TMA serves as indication that the data packet has been successfully copied into the receive buffer at the destination station. This flag may be cleared by LLC functions and is automatically cleared when TA is cleared.

The case where both TA and TMA are set is indication of guaranteed delivery into a receiver buffer at the destination. The setting of TA while TMA remains clear is an indication of probable failure of the data packet delivery. However, the destination station may have successfully received the data packet even when TA is set while TMA remains clear at the source station (for example, in cases where the ACK frame is destroyed by a RECON Burst.).

3.4.4 Reconfiguration (RECON)

This flag is set when the activity timer (TAC) expires, indicating that a network reconfiguration needs to occur. This flag is cleared by LLC or NMT functionality as appropriate.

3.4.5 Broadcast Enabled (BE)

This flag is set and cleared as desired by LLC or NMT functionality. When this flag is set, reception of broadcast data packets by this station is enabled. When this flag is cleared, broadcast data packets are ignored by this station.

3.4.6 PAC Detected (PF)

This is an internal flag which is set when the FID of an incoming frame is decoded as being a PAC. This flag is set and cleared by the operational finite-state machine.

3.4.7 ITT Detected (IF)

This is an internal flag which is set when the FID of an incoming frame is decoded as being an ITT. This flag is set and cleared by the operational finite-state machine.

3.4.8 FBE Detected (FF)

This is an internal flag which is set when the FID of an incoming frame is decoded as being an FBE. This flag is set and cleared by the operational finite-state machine.

3.5 Registers

Registers are used to remember a particular value. They are loaded as specified in the finite state machine definitions.

3.5.1 My Identifier (MYID)

This is an 8-bit register which contains the specified address of this station and is used to insert source identification field contents in outgoing data packets and as a reference for incoming address recognition.

3.5.2 Next Identifier (NID)

This is an 8-bit register which holds the station address of the successor station on the logical ring and is used to address the token on token passes from this station.

3.5.3 Transmit Destination (TXD)

This is an 8-bit register which holds the destination station address of the current outgoing data packet (if any). This is used to designate the intended recipient(s) of the outgoing packet.

3.5.4 Received Destination (RXD)

This is an 8-bit register which holds the destination station address received in the current incoming data packet (if any). This is used to distinguish received broadcast packets from explicitly-addressed packets.

4. ARCNET Protocol

This section specifies the procedures that are used in the Medium Access Control (MAC) sub-layer.

4.1 Overview

The subsections of 4.1 provide a descriptive overview of frame transmission and reception. The formal specification of the operation of basic ARCNET is given in 4.2.

4.1.1 Frame Transmission

Access to the physical medium is controlled by the passing of a token around a logical ring determined by the sequence of ascending station addresses, and without regard to the physical distribution of these stations about the physical medium. The station in receipt of the token has the opportunity to transmit a frame or group of frames, including not more than one data packet. Upon request for transmission of an LLC PDU or NMT PDU, MAC prefixes the PDU with the appropriate SD, FID, and address fields and enqueues the PDU to wait for the reception of a token that may be used for its transmission.

If the DID of the PDU is zero (indicating a broadcast), upon receipt of a token, the station

(1) sends the data packet frame, and

(2) after waiting the broadcast delay (TBR) the station generates an ITT frame to pass the token to the next station on the logical ring.

If the DID of the PDU is non-zero (indicating an explicitly addressed destination), upon receipt of the token, the station

(1) transmits an FBE frame,

(2) waits for a responding ACK or NAK frame from the addressed destination, and

(3) sends the data packet frame if an ACK was received in response to the FBE.

(4) After sending the data packet frame, the station again waits for an ACK frame from the destination.

(5) After receiving this final ACK (or exceeding the specified time-out without receiving the ACK), the station generates an ITT frame to pass the token to the next station on the logical ring.

4.1.2 Reconfiguration Burst Transmission

When network reconfiguration is needed, as detected by power-on reset conditions or the TLT time-out at the station, the station activates its transmitter to transmit a reconfiguration burst. The reconfiguration burst does not communicate useful information, and is used to force network (re-)initialization by terminating all activity on the network. Network activity may be terminated in this manner because the reconfiguration burst is longer than any type of frame and will, therefore, interfere with the next ITT frame. By interfering with the ITT frame, the reconfiguration burst prevents any station from receiving the token. This will ultimately result in a TAC and/or TLT time-out at all stations.

4.1.3 Frame Reception

Stations, while receiving the incoming symbol stream, check for frames to be acted upon. If the FID indicates a MAC frame (any of ITT, ACK, PAC, FBE, or NAK), the frame control information is interpreted by all stations on the network. In addition, if the frame is a PAC and the frame's DID field matches the station's assigned address or broadcast address, the SID, DID, IL, SC, and INFO fields are copied to a receive buffer and subsequently forwarded to the appropriate sublayer.

4.2 Specification -- Basic ARCNET

Operation of the network is described in this section. In the case of a discrepancy between the FSM diagram/tables and the supporting text, the FSM diagram/tables shall take precedence.

The MAC receives from the PHY layer a serial stream of basic symbols. Each basic symbol shall be one of the following (see Section 6 for a detailed description of these symbols):

0 = binary zero
1 = binary one

From the received symbols, MAC detects various types of frames including MAC frames and LLC information frames. In turn, MAC stores values, sets flags, controls timers, and performs various internal actions, as well as generating tokens, frames, and reconfiguration bursts and delivering them to the PHY layer.

4.2.1 Receive Actions

The receiver discriminates between two varieties of frames: validly formed frames and bad frames (FR_BAD). A validly formed frame:

(1) begins with a valid SD,
(2) has an FID value for ITT, ACK, PAC, FBE, or NAK immediately following the SD,
(3) contains an integral number of ISUs from among 1, 3, 8 to 260, or 265 to 516 following the SD,
(4) has at least two binary ones and exactly one binary zero preceding the information byte in each ISU,
(5) has equal values in both ISUs of the DID field (for ITT, FBE, and PAC frames only),
(6) has a valid FCS (for PAC frames only), and
(7) has at least nine binary zeros following the last ISU.

A bad frame is any frame which does not meet all of these requirements.

4.2.2 Finite-State Machine

The operational finite-state machine is illustrated in Figures 4.1, 4.2, and 4.3, and explained as follows:

4.2.2.1 (x1) Power-On Reset

Whenever a station is powered on, or is allowed to become active on the network in cases where initialization of network activity is inhibited after power-on, an immediate entry is made to State 0.

NOTE: It is undesirable to implement a station in such a manner that software control of the Power-On Reset function is possible, since each occurrence of POR causes a Reconfiguration Burst, which disrupts network communication and reduces usable throughput.

4.2.2.2 (x2) Lost Token Timeout

Whenever TLT times out, an immediate transition to State 0 occurs, independent of what is occurring elsewhere in the operational FSM.

4.2.2.3 State 0: Reset

In Reset State any necessary physical initialization is performed before forcing network reconfiguration.

(01) Exit from Reset State
As soon as physical initialization is completed, a Reconfiguration Burst is transmitted to force network reconfiguration; token loop regeneration is prepared by setting NID to MYID; the TLT and TMQ timers are reset; and a transition is made to State 1. State 1 is entered here so that this station will wait if another Reconfiguration Burst is in progress.

4.2.2.4 State 1: WT_IDLE (Wait for Quiescent Medium)

While in this state the station waits until it detects silence (continuous binary zeros) on the medium for the TMQ interval.

(11) Loop on Activity
If a binary one is detected, the TMQ timer is reset and the station stays in State 1.

(12) Exit on Silence
If TMQ times out, this means that no valid network activity is occurring, since all symbol units include at least one binary one every TMQ interval. When TMQ times out, TAC is reset and a transition is made to State 2 to wait for new activity.

4.2.2.5 State 2: WT_ACTV (Wait for Activity on Medium)

While in this state the station waits up to the TAC interval for activity (binary ones) on the medium. If activity is detected, the new frame is decoded. If TAC times out, network reconfiguration occurs.

(21) Activity Detected
When a binary one is detected, this indicates the beginning of an SD (or a Reconfiguration Burst, which will end up being ignored due to FR_BAD). The remaining ones in the SD are bypassed; the PF, IF, and FF flags are reset to prepare for frame type decoding; and entry to State 3 is made as soon as the first binary zero (which will be the third symbol of the FID ISU) is detected.

(22) No Activity Detected
If TAC times out then no network activity is occurring, which means that network reconfiguration is required to regenerate the token loop. TIP is reset to cause the reconfiguration process to start at the active station with the highest ID; NID is set to this station's ID to set up for polling of possible successor stations on the token loop; and the RECON flag is set to indicate to NMT that a network reconfiguration has occurred.

4.2.2.6 State 3: DCD_TYPE (Decode Frame Type)

In this state the FID field of the frame being received is decoded to determine the frame type.

(31) Frame Not Acceptable
The incoming frame cannot be accepted if the FID indicates a type other than PAC, FBE, or ITT; if the FID indicates a PAC but the receiver is inhibited (RI is set); or if the frame has invalid format (FR_BAD). In any of these cases TMQ is reset and a transition is made to State 1 to wait for the end of this frame. If State 3 was entered due to detection of binary ones from a Reconfiguration Burst, transition 31 occurs due to FR_BAD and the remainder of the Reconfiguration Burst is ignored by looping in State 1 through transition 11.

(32) FBE Detected
The incoming frame is an FBE, so FF is set to remember this frame type and entry is made to State 4 to decode the DID.

(33) ITT Detected
The incoming frame is an ITT, so IF is set to remember this frame type and entry is made to State 4 to decode the DID.

(34) PAC Detected (with RI clear)
The incoming frame is a PAC and PAC reception is enabled (RI clear), so PF is set to remember this frame type, the SID field is stored into the receiver buffer, and entry is made to State 4 to decode the DID.

4.2.2.7 State 4: DCD_DID (Decode Destination Identifier)

In this state the first ISU of the DID field is inspected to distinguish between frames addressed to this station, broadcast frames (if reception of broadcasts is enabled), and frames addressed to other stations.

(41) DID Not Acceptable
The incoming frame is rejected based on its DID if that DID is zero on either a FBE or ITT; if that DID is zero on a PAC when broadcast reception is not enabled (BE clear); if that DID is neither zero nor this station's ID; or if the DID field has invalid format (FR_BAD). In any of these cases TMQ is reset and a transition is made to State 1 to wait for the end of this frame.

NOTE: Unequal values in the two ISUs of the DID field of an incoming PAC frame are a case of FR_BAD, and can be rejected through transition 41; however, it is acceptable for the receiver to store such a PAC into the receiver buffer, by making transition 45 based on the value of the first ISU of the DID field (assuming other framing requirements are met), and to subsequently reject the PAC in transition 131 due to the FR_BAD condition from the unequal DID ISU values.

(42) FBE Addressed to Station
The incoming FBE is addressed to this station and is valid, so TTA is reset to ensure proper line turnaround and entry is made to state 6 to respond to the FBE.

(43) ITT Addressed to Station When No Transmission Pending
The incoming ITT is addressed to this station and is valid, but this station has no PAC awaiting transmission (TA), so TTA is reset to ensure proper line turnaround and entry is made to state 7 to pass the token immediately.

(44) ITT Addressed to Station When Transmission Pending
The incoming ITT is addressed to this station and is valid when this station has a PAC awaiting transmission (~TA), so TTA is reset to ensure proper line turnaround and entry is made to state 9 to begin the PAC transmit sequence.

(45) PAC Addressed to Station or Broadcast
The incoming PAC is valid and is either addressed to this station or is a broadcast (while reception of broadcasts is enabled), so the incoming DID (second ISU only), IL, SC, and INFO fields are stored into the receiver buffer and transition is made to state 13 to complete reception of the PAC.

4.2.2.8 State 5: RECON (Network Reconfiguration)

In this state network reconfiguration begins by monitoring for network activity while waiting for the time-out of TIP. If this time-out occurs this station begins the reconfiguration process by commencing with token passing. If network activity is detected before this time-out occurs, then some other station has initiated token passing, so this station can suspend its reconfiguration attempt.

(51) Activity Detected
Activity has been detected before the time-out of TIP, indicating that a station with a higher ID is active on the network and has begun the reconfiguration process. TIP is stopped, and entry is made to State 1 with TMQ reset to cause the remainder of the detected activity to be ignored.

NOTE: Unlike activity detected when in State 2, the activity detected when in State 5 is not decoded as to type. This is why it is necessary that the first attempted token pass of the reconfiguration process must be to MYID, not to MYID+1.

(52) TIP Timeout
TIP has timed out before any activity has been detected, indicating that this station has the highest active ID and must (re)establish the token loop. TLT and TRC are reset and entry is made to State 7 to begin token passing.

4.2.2.9 State 6: RX_FBE (Respond to FBE)

This state is entered when this station has received an FBE and must generate a response upon time-out of TTA.

(61) Respond to FBE with ACK
The RI flag is clear, indicating that the receiver is enabled and a receive buffer is available, so an ACK is transmitted and entry is made to State 1 to wait for the medium to become silent.

(62) Respond to FBE with NAK
The RI flag is set, indicating that the receiver is disabled and/or no receive buffer is available, so a NAK is transmitted and entry is made to State 1 to wait for the medium to become silent.

4.2.2.10 State 7: PASS_TOKEN

The token is passed to NID.

(71) Send ITT
Upon time-out of the TTA (turnaround), TRC (recovery), or TBR (broadcast delay) timer, an ITT is sent to NID; the TRP (response) and TRB (receiver blanking) timers are reset; the TTA, TRC, and TBR timers are stopped; and entry is made to State 8 to await a response to the token.

4.2.2.11 State 8: WT_TOKEN (Wait for Activity After Passing Token)

In this state the station monitors the medium after passing the token to determine if another active station has received the token and commenced network activity. If so, this activity is decoded; if not, this station's NID is incremented and token passing is retried.

(81) No Response to Token
The expiration of TRP without detection of network activity indicates that the token has not been received by an active station. To continue attempting to locate an active NID, the value of NID is incremented (modulo 256) and State 7 is entered to attempt a token pass to the new NID value.

(82) Response to Token
The detection of activity (a binary one) before the expiration of TRP indicates that the token has been accepted by another active station. The remaining ones in the SD are bypassed; the PF, IF, and FF flags are reset to prepare for frame type decoding; TRP is stopped; and entry to State 3 is made as soon as the first binary zero (which will be the third symbol of the FID ISU) is detected. This entry to State 3 is equivalent to transition 21.

4.2.2.12 State 9: TX_FBE (Transmit FBE)

This state is entered when a PAC is to be transmitted and the token has been received. If the PAC is a broadcast, no action is taken and immediate packet transmission (State 11) occurs. If the PAC is not a broadcast an FBE is transmitted to determine if the destination station has its receiver enabled and has a buffer available to accept the PAC.

(91) Send FBE
If the DID of the pending PAC is non-zero, an FBE is sent and entry is made to State 10 to wait for response to this FBE.

(92) Do Not Send FBE
If the DID of the pending PAC is zero, indicating a broadcast, no action is taken and immediate entry is made to State 11 to transmit the PAC.

4.2.2.13 State 10: WT_FBE (Wait for Reply to FBE)

In this state the station waits for a response to an FBE. If the response is an ACK, the PAC is transmitted. If the response is a NAK, the token is passed and the transmission remains pending. If the response is invalid or does not occur, the transmission is aborted.

(101) No Response to FBE
If TRP expires without any incoming activity the transmission is aborted (TA set) and entry is made to State 7 to pass the token.

(102) NAK in Response to FBE
If a NAK is received, the transmitter remains enabled (TA remains clear) and entry is made to State 7 to pass the token. Because TA remains clear, the transmission will be re-attempted when the next token is received by this station.

(103) ACK in Response to FBE
If an ACK is received entry is made to State 11 to transmit the PAC.

(104) Response to FBE Which is Neither ACK nor NAK
If activity is detected which is neither an ACK nor a NAK, whether validly framed or not, the transmission is aborted and State 1 is entered to ignore any remaining activity in the frame. This has the effect of forcing network reconfiguration because this station does not pass the token. The reasoning behind this is that any situation where an FBE response does occur, but is neither an ACK nor a NAK, the network probably needs reconfiguration. Because TA remains clear, the transmission will (eventually) be re-attempted.

4.2.2.14 State 11: TX_PAC (Transmit PAC)

The pending PAC transmission is sent.

(111) Non-broadcast PAC
If the DID of the PAC is non-zero, the PAC is sent and entry is made to State 12 to wait for a response to the PAC.

(112) Broadcast PAC
If the DID of the PAC is zero, indicating a broadcast, the PAC is sent, the transmitter is disabled (TA set), and entry is made to State 7 to pass the token.

4.2.2.15 State 12: WT_PAC (Wait for Reply to PAC)

In this state the station waits for a response to a PAC. If the response is an ACK, successful delivery is indicated and the token is passed. If the response is invalid or does not occur, the token is passed without indicating successful delivery.

(121) No ACK Received
If TRP expires without any incoming activity, or if the detected activity is invalid or is not an ACK, the transmitter is disabled (TA set) and entry is made to State 7 to pass the token.

(122) ACK Received
If an ACK is received the message acknowledgement flag (TMA) is set, the transmitter is disabled (TA set), and entry is made to State 7 to pass the token.

4.2.2.16 State 13: RX_PAC (Complete Reception of PAC)

In this state the PAC has been received and the FCS must be checked and appropriate completion action taken.

(131) PAC Invalid
The PAC is invalid due to a framing error, FCS error, or mismatch of DID bytes. No confirmation is sent and entry is made to State 1 to wait for the medium to become idle.

(132) Broadcast PAC Received Successfully
The PAC is valid and is a broadcast, for which no acknowledgement is to be sent. The receiver is inhibited (RI set) and entry is made to State 1 to wait for the medium to become idle.

(133) Non-Broadcast PAC Received Successfully
The PAC is valid and is addressed to this station. The receiver is inhibited (RI set), TTA is reset to generate an interframe gap, and entry is made to State 14 to generate an ACK.

4.2.2.17 State 14: PAC_ACK (Send Reply to PAC)

This state is entered after successful receipt of a non-broadcast PAC to send the confirming ACK.

(141) Send ACK
An ACK is sent and entry is made to State 1 to wait for the medium to become idle.

4.2.2.18 State Transition Diagrams

A legend of FSM notation appears in section 1.3.

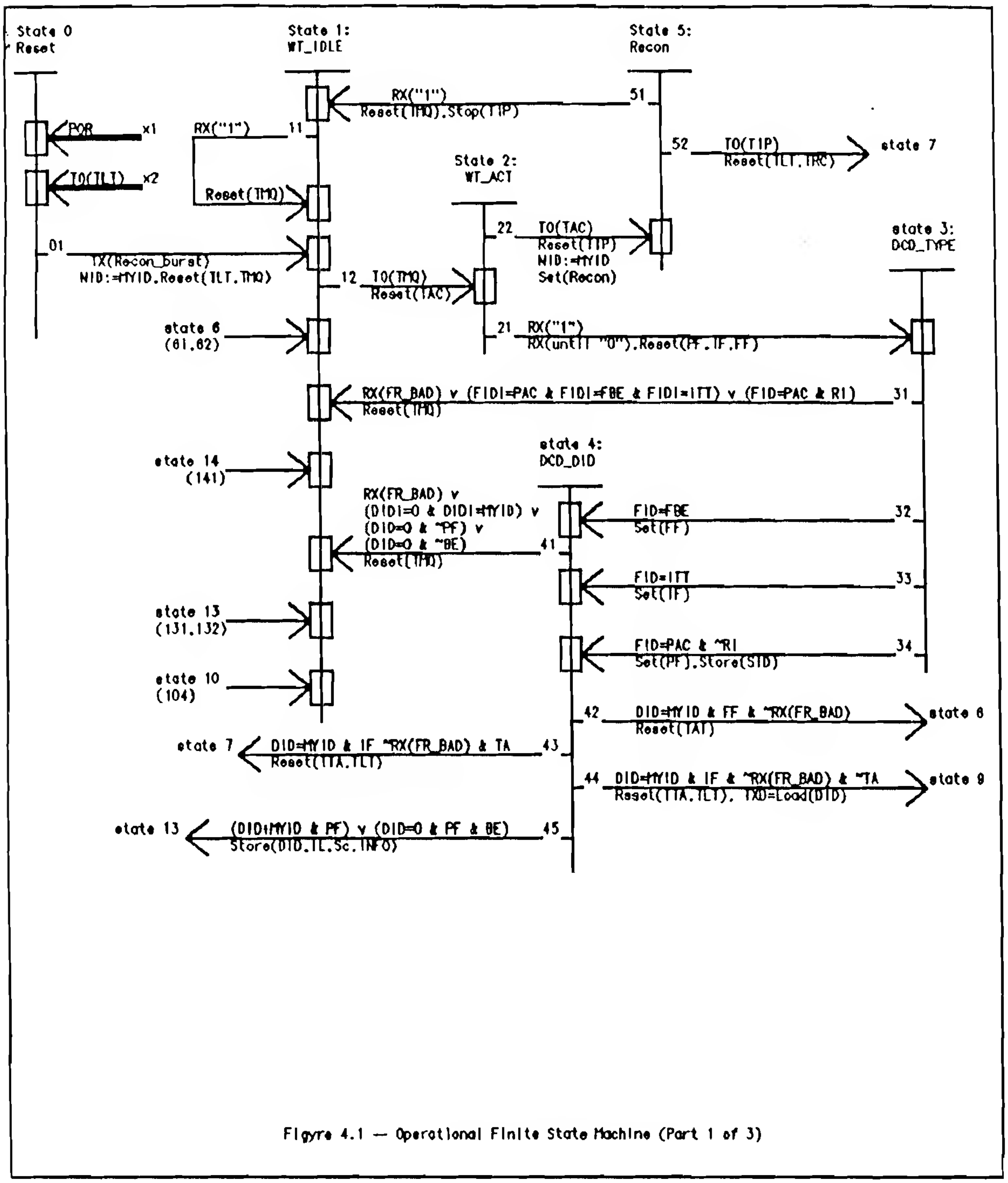


Figure 4.1 -- Operational Finite-state Machine (Part 1 of 3)

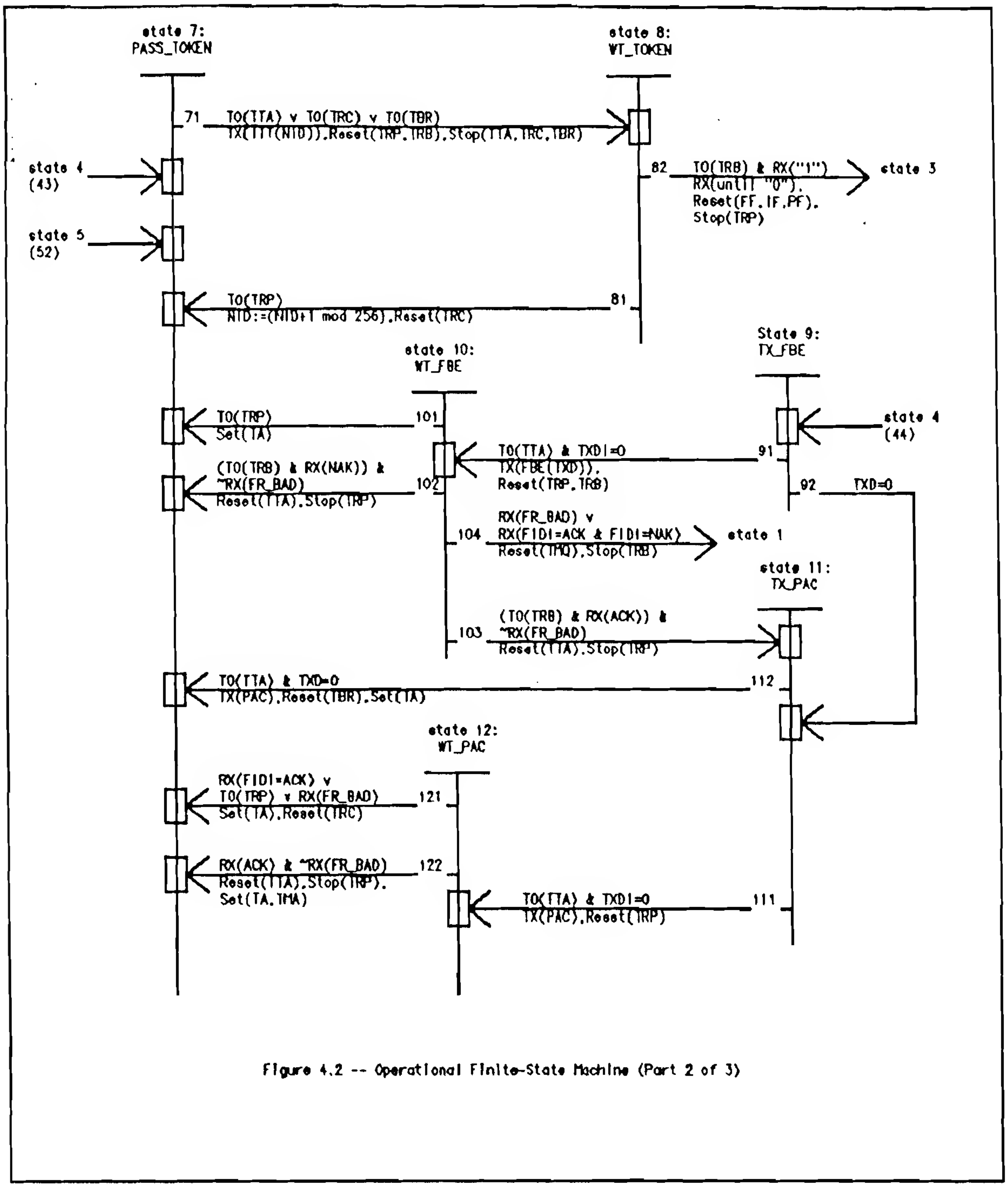


Figure 4.2 -- Operational Finite-state Machine (Part 2 of 3)

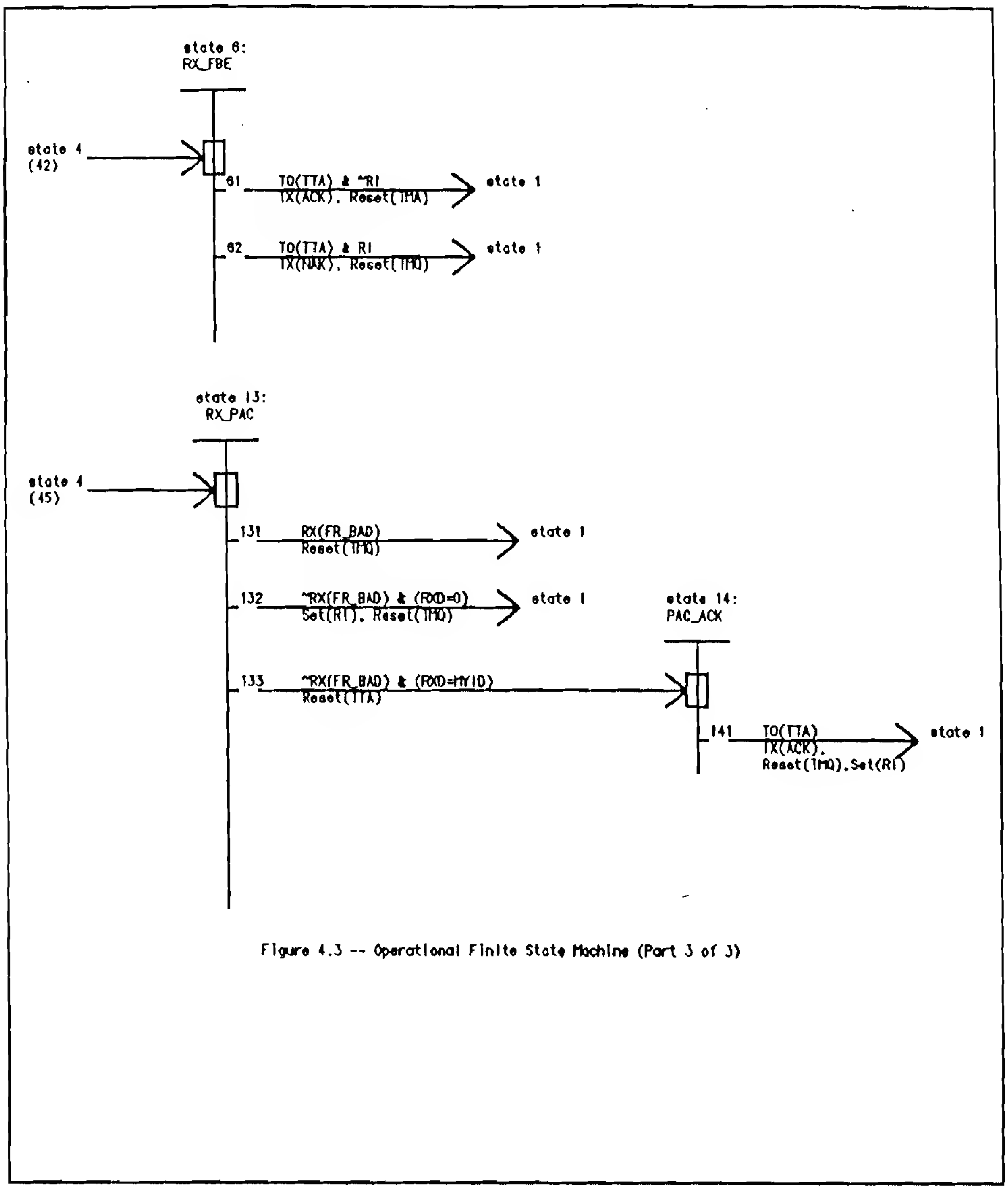


Figure 4.3 -- Operational Finite-state Machine (Part 3 of 3)

5. Service Specifications

This section specifies the services provided:
(1) By the MAC sublayer to the logical link control (LLC) sublayer,
(2) by the PHY layer to the MAC sublayer,
(3) by the MAC sublayer to NMT, and
(4) by the PHY layer to NMT.
The services are described in an abstract manner and do not imply any particular implementation or any exposed interface.

Specification to other layers called out by the Open System Interconnect Basic Reference Model define multiple instantiations of the layer's state machine. Session layer, for example, creates an instantiation of its machine for every established session. The MAC sublayer has only one instance of the state machine described in this document. It recognizes only one user above it and one Physical layer below it. The MAC does not keep track of packets based on destination. It is up to the MAC user to perform this function.

5.1 MAC to LLC Service

This section specifies the services required of the MAC sublayer by the LLC to allow the local LLC sublayer entity to exchange LLC data units with peer LLC sublayer entities.

5.1.1 Interactions

The following primitives are defined for the LLC sublayer to request service from the MAC sublayer:
MA_DATA.request
MA_DATA.indication
MA_DATA.confirmation
All primitives described in this section are mandatory.

5.1.2 Detailed Service Specifications

All primitives are specified in an exemplary form only. Each service names the particular primitive and the required information that is passed between the LLC sublayer and the MAC sublayer.

5.1.2.1 MA_DATA.request

This primitive defines the transfer of a MAC SDU from a local LLC sublayer entity to a single peer LLC entity, or multiple peer LLC entities in the case of a broadcast.

Semantics of the service primitive:

```
MA_DATA.request (
                  system_code,
                  destination_address,
                  M_SDU
                  )
```

The system_code parameter specifies the value for the frame's SC field. The destination_address parameter may specify either an individual destination ID or a broadcast address and is used to specify the contents of the DID field. The M_SDU parameter specifies the MAC service data unit to be transmitted by the MAC sublayer entity. There is sufficient information associated with the M_SDU for the MAC sublayer entity to determine the length of the data unit.

When generated:
This primitive shall be generated by the LLC sublayer entity whenever data must be transferred to a peer LLC entity or entities. This can be in response to a request from higher layers of protocols or from data generated internally to LLC sublayer.

Effect of Receipt:
The receipt of this primitive shall cause the MAC entity to append all MAC fields, including SID, DID, and FID, and pass the properly formed frame to the PHY layer for transfer to the peer MAC sublayer entity or entities.

5.1.2.2 MA_DATA.indication

This primitive defines the transfer of data from a MAC sublayer entity to the LLC sublayer entity or entities in the case of a broadcast.

Semantics of the service primitive:

```
MA_DATA.indication    (
                      system_code,
                      destination_address,
                      source_address,
                      M_SDU
                      )
```

The system_code parameter is the SC field received. The destination address parameter may be either an individual address or a broadcast address as specified by the DID field of the received frame. The source address parameter must be an individual address as specified in the SID field of the incoming frame. The M_SDU parameter shall specify the MAC service data unit as received by the local MAC entity.

When generated:
The MA_DATA.indication primitive shall be generated by the MAC sublayer entity to the LLC sublayer entity or entities to indicate the arrival of an LLC frame at the local MAC sublayer entity. Such frames shall be reported only if they are validly formed and their destination address matches the designated local MAC entity or designates a broadcast.

Effect of Receipt:
The effect of receipt of this primitive by the LLC sublayer is dependent upon the content of the frame.

5.1.2.3 MA_DATA.confirmation

This primitive has local significance and shall provide an appropriate response to the LLC sublayer MA_DATA.request primitive signifying the success or failure of the request.

5.1.3.3 Exception: Nonexistent Node

In this example, the correspondent entity does not currently exist on the network medium. Therefore, no ACK_PDU is received by the sending node in response to the FBE_PDU (Free Buffer Enquiry).

```
MA_DATA.request -------> ||                  ||
                         ||  -- FBE_PDU ->   ||
                         ||  (no response)   ||
MA_DATA.confirmation  <- ||                  ||
        Service               Protocol            Service
```

5.1.3.4 Exception: No Free Buffer

When the corespondent node exists on the network medium but does not have a free buffer to receive the transmission, the node replies with a NAK_PDU (Negative Acknowledge). The transaction does not end at this point, however. Upon each reception of the token, the sending node retries the transaction until successful or commanded to abort the operation by the LLC.

```
MA_DATA.request -------> ||                  ||
                         ||  -- FBE_PDU ->   ||
                         ||  <- NAK_PDU --   ||
                         ||                  ||
        Service               Protocol            Service
```

5.2 PHY to MAC Service

The services provided by the PHY layer allow the local MAC sublayer entity to exchange MAC data units with peer MAC sublayer entities. Note that all PHY data units have the duration of one symbol.

5.2.1 Interactions

The following primitives are defined for the MAC sublayer to request service from the PHY layer:

PHY_DATA.request
PHY_DATA.indication
PHY_DATA.confirmation

All primitives described in this section are mandatory.

5.2.2 Detailed Service Specifications

All primitives are specified in an exemplary form only. Each service shall name the particular primitive and the required information that shall be passed between MAC sublayer and the PHY layer.

5.2.2.1 PH_DATA.request

This primitive defines the transfer of data from a local MAC sublayer entity to the station's PHY layer.

Semantics of the service primitives:

```
PHY_DATA.request     (
                     symbol
                     )
```

Semantics of the service primitive:

```
MA_DATA.confirmation    (
                          transmission_status
                        )
```

The transmission status parameter shall be used to pass information back to the local requesting LLC sublayer entity. It shall be used to indicate the success or failure of the previous associated MA_DATA.request.

When generated:
This primitive shall be generated by the MAC entity in response to an MA_DATA.request primitive from the local LLC sublayer entity.

Effect of Receipt:
The effect of receipt of this primitive by the LLC sublayer is unspecified.

Additional comments:
It is assumed that sufficient information is available to the LLC sublayer to associate the response with the appropriate request.

5.1.3 Service Event Diagrams

The following paragraphs provide a nonexhaustive list of events to illustrate the workings of the MAC to LLC interface and the resultant MAC-to-MAC communications.

5.1.3.1 Normal Series of Events - Non-Broadcast

When the LLC generates a non-broadcast MA_DATA.request, the MAC generates an FBE_PDU, (Free Buffer Enquiry). Upon reception of an ACK_PDU (Acknowledge), the MAC sends a PAC_PDU (Packet) which is the encapsulated M_SDU service data unit. Upon reception of an other ACK_PDU, the MAC signals the LLC with a MA_DATA.confirmation.

```
MA_DATA.request ------->  ||                  ||
                          || -- FBE_PDU ->    ||
                          || <- ACK_PDU --    ||
                          || -- PAC_PDU ->    ||
                          || <- ACK_PDU --    ||  --> MA_DATA.indication
MA_DATA.confirmation  <-  ||                  ||
       Service                 Protocol             Service
```

5.1.3.2 Normal Series of Events - Broadcast

When the LLC generates a broadcast MA_DATA.request, the MAC sends a PAC_PDU (Packet) which is the encapsulated M_SDU service data unit. Upon completion of the transmission, the MAC signals the LLC with a MA_DATA.confirmation.

```
MA_DATA.request ------->  ||                  ||
                          || -- PAC_PDU ->    ||
                          ||                  ||  --> MA_DATA.indication
MA_DATA.confirmation  <-  ||                  ||
       Service                 Protocol             Service
```

When generated:
The PHY layer shall send the MAC sublayer PH_DATA.confirmation in response to every PH_DATA.request received by the PHY layer. The purpose of the PHY_DATA.confirmation is to synchronize the MAC sublayer data output with the data rate of the PHY layer medium.

Effect of Receipt:
The receipt of this primitive enables the MAC sublayer to send another PH_DATA.request to the PHY layer.

Additional comments:
The PHY layer provides synchronous service. That is, upon completion of a PH_DATA.confirmation it expects an immediate PH_DATA.request.

5.4 PHY to NMT Service

The services provided by the PHY layer to NMT allow the local NMT to control operation of the PHY layer.

5.4.1 Interactions

The following primitives are defined for the NMT to request services from the PHY layer:

PH_CONTROL.request

The primitive described in this section is mandatory.

5.4.2 Detailed Service Specifications

This primitive is specified in exemplary form only. Service shall name the primitive and specify the information that shall be passed between PHY and NMT.

5.4.2.1 PH_CONTROL.request

This primitive shall be generated by the NMT to request the PHY layer to insert or remove itself from the logical token loop.

Semantics of the control primitive:

```
PH_CONTROL.request (
                        control_action,
                        station_address
                        )
```

The control_action parameter shall be one of the following:

Insert - To cause insertion into the token loop.
Remove - To cause removal from the token loop.

The station_address is the network address of this station, and is only meaningful when the control_action is "Insert".

When generated:
This primitive shall be generated by the NMT when the NMT requires insertion or removal of the station from the network.

Effect of Receipt:
The PHY layer shall take appropriate action to cause insertion or removal from the network.

The symbol specified shall be one of the following:

0 = binary zero
1 = binary one

When generated:
The MAC sublayer shall send the PHY layer a PH_DATA.request every time the MAC sublayer has a symbol to output. Once the MAC sublayer has sent a PH_DATA.request to the PHY layer, it may not send another PH_DAT.request until it has received a PHY_DATA.confirmation from the PHY layer.

Effect of Receipt:
Upon receipt of this primitive, the PHY entity shall encode and transmit the symbol. When the PHY entity is ready to accept another PH_DATA.request it shall return to the MAC sublayer a PH_DATA.confirmation.

5.2.2.2 PH_DATA.indication

This primitive defines the transfer of data from the PHY layer to the MAC sublayer entity.

Semantics of the service primitive:

```
PH_DATA.indication   (
                     symbol
                     )
```

The symbol shall be defined as one of the following:

0 = binary zero
1 = binary one

When generated:
The PHY layer shall send the MAC sublayer a PH_DATA.indication every time the PHY layer decodes a symbol. This indication is sent once every symbol.

Effect of Receipt:
Upon receipt of this primitive, the MAC sublayer accepts a symbol from the PHY layer.

5.2.2.3 PH_DATA.confirmation

This primitive has local significance and shall provide an appropriate response to the MAC sublayer PH_DATA.request primitive signifying the acceptance of a symbol specified by the PH_DATA.request and willingness to accept another symbol.

Semantics of the service primitive:

```
PH_DATA.confirmation (
                     transmission_status
                     )
```

The transmission_status parameter shall be used to signify the transmission completion status.

6. Physical Layer

This section defines the physical (PHY) specifications. These include data symbol encoding and decoding, symbol timing, and data reliability. The specifications in this section are applicable to all station attachment specifications but are not specific to any particular station attachment specification.

6.1 Symbol Encoding

The PHY layer encodes and transmits the information presented to it at its MAC interface by the MAC sublayer. The information exchanged between the MAC and PHY are streams of binary zeros and ones. The data are presented in the Non-Return to Zero (NRZ format) for encoding as appropriate for the particular station attachment specification.

6.2 Data Signalling Rate

The basic data signalling rate is 2.5Mbps. The permitted tolerance for this signalling rate is +/-0.01%.

6.3 Symbol Timing

The PHY layer recovers symbol timing based on information inherent in transitions of the received signal. This is facilitated by the use of frame formats with guaranteed, minimum periodicity of binary ones.

The maximum allowed cumulative jitter in the received signal is +/-25ns between any signal transitions within any single ISU. This cumulative jitter specification applies to the entire transmitter-to-receiver path during any network communication, including any repeaters or hubs along this path. Accordingly, the worst-case jitter characteristics on each individual transmitter, receiver, and repeater must be substantially better than this cumulative figure to ensure reliable network operation. Recommended practice is to limit any individual entity to less than 10% of the total jitter allowance.

6.4 Symbol Decoding

The PHY layer receives information presented to it and presents the decoded information to the MAC interface. The information exchanged between the MAC and PHY are streams of binary zeros and ones. The information is decoded as appropriate for the particular station attachment specification and presented to the MAC layer in the Non-Return to Zero (NRZ format)

7. Station Attachment Specifications -- Electrical Cable

7.1 Scope

This section specifies the functional, electrical, and mechanical characteristics of the baseband electrical attachment to the ARCNET interconnect cabling.

Compliance with the specifications in this chapter provides for compliance with methods /C, /T, /S, and /B as shown in section 1.2.4 (page 6). Other methods of connections exist and do not preclude compliance with base ARCNET.

7.2 Overview

The function of the ARCNET interconnect medium is to transport data symbols among all stations on the network. This communications medium may include a variety of different cable types, as well as hubs and/or repeaters, provided that the propagation, attenuation, and jitter specifications of this section are met.

The medium interface cable, may be a single cable section or may include multiple sections of cable joined by connectors identical to the MIC. By definition, the MIC is the connector at which all transmitted and received signal specifications must be met.

7.3 Basic Signal Characteristics

7.3.1 Transmitted Signals

7.3.1.1 Data Signalling Rate

The basic data signalling rate is 2.5Mbps. The permitted tolerance for this signalling rate is +/-0.01%.

7.3.1.2 Signal Level

The minimum magnitude of the transmitted signal, measured at the MIC with a 93ohm resistive termination, is 15.4V, peak to peak. The amplitude of the positive and negative portions of the dipulse shall be balanced to within 10%.

7.3.1.3 Signal Envelope

The basic signal shall be a single sine pulse of period 200ns left justified in a 400ns interval as is shown below.

In the diagram below, the function

* f(t) = sin(2 * PI * t / 200ns) when 0 <= t < 200ns
  0 otherwise

and

* g(t) = 1 when 0 <= t < 100ns
  -1 100ns <= t < 200ns
  0 otherwise

7.3.2.2 Signal Attenuation

The maximum attenuation of the network signal, relative to the minimum transmitted amplitude, is 11dB.

7.3.2.3 Signal Jitter

The maximum cumulative deviation of a received symbol from the ideal transmission, due to both timing distortion and jitter, may not exceed +/-25ns measured relative to the first bit of the current ISU.

7.3.2.4 Receiver Impedance

For star-topology systems, the receiver shall present an impedance of 93 +/- 25 ohms.

For bus-topology systems, the receiver shall present an impedance of at least 1.2K ohms regardless of the node's operating condition (power-on, power-off, transmit disabled, etc.).

7.3.2.5 Receive Filtering

The received signal shall be filtered by a matched filter designed as a trignometric pulse-forming network and matched to a 5MHz sine pulse.

7.3.2.6 Signal Level

The received signal at the MIC shall have a magnitude of at least 4.34V peak to peak. The received signal at the output of the receive filter shall have a peak amplitude of at least 520mV for at least 25ns.

7.3.2.7 Error Rate

The station receivers shall provide an output with an error rate of less than 1 bit in error for every 10^{12} bits transmitted when other signalling characteristics of the section are met.

7.4 Safety and Grounding Requirements

All stations meeting this standard shall conform to either IEC Standard 380 (office machinery) or IEC Standard 435 (data processing equipment). All exposed materials shall meet appropriate flammability requirements. Low smoke and fume materials shall be used as mandated by local requirements.

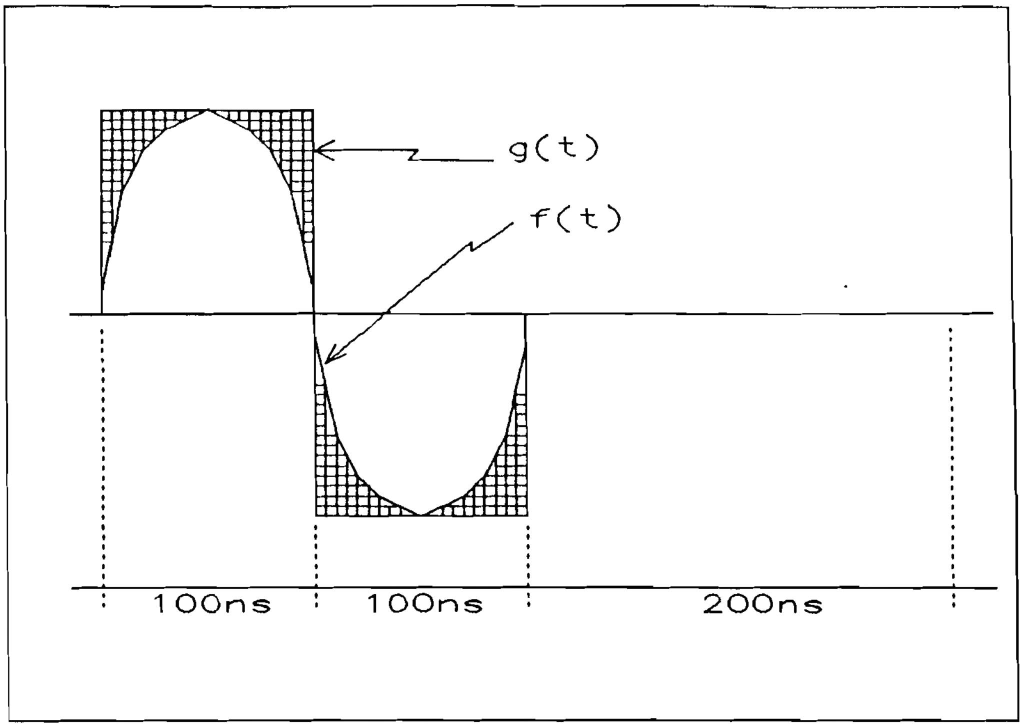
7.5 Medium Interface Connector (MIC)

The Medium Interface Connector is medium dependent, as detailed below.

7.5.1 Coaxial Cable

The MIC for use with coaxial cable is a conventional, 50 or 75 ohm, female BNC.

Sample part numbers:
AMP 228686-1



Basic Signal Envelope

7.3.1.4 Measurement

Compliance with the above specification is determined by convolving a candidate waveform with a single 200ns sine pulse (2 volts peak to peak) and verifying that the amplitude of the result of the convolution at t=200ns is at least 15.4 volts.

7.3.2 Received Signals

7.3.2.1 Signal Delay

The total delay imposed by the medium (including cables as well as any hubs, repeaters, or other communication elements) may not exceed 31.0us when using standard timeouts. The signal delays for other time-out settings are shown in the table below. Extended time-out level settings may not be mixed on a single network.

Signal Delay Limits	
Timeout Mode	Maximum Signal Delay
0*	31.0us
1	142.9us
2	292.1us
3	590.5us

* - Default setting

8. Active Hub Specification

8.1 Scope

This section defines the functional characteristics of active hubs for use with star topology ARCNET. This section does not define the electrical or mechanical characteristics of the hub. Active hubs may be employed with star topology networks, using any form of cabling or other interconnect media, which meet the attachment specifications of this standard.

Passive hubs are considered part of the interconnect media, and are not covered herein, because they merely attenuate the signal while splitting it among several ports.

8.2 Overview

An active hub is a device which provides for selective connection of groups of cables, with each cable connecting to a station or to another active hub. The active hub implements cable segment isolation, wiring concentration, signal repeating, and echo cancelation. Under ordinary circumstances active hubs do not interpret the signals which they repeat. However, active hubs which provide features such as network management or media type conversion may be implemented as a superset of the functionality defined herein.

8.3 Active Hub Finite State Machine

The active hub imposes a priority upon its ports, based upon the first port from which it detects incoming activity during any particular signal repeating event. Assigning a fixed set of relative priorities among these ports is acceptable for resolving incoming activity conflicts which occur due to detecting input signals simultaneously on two or more ports. However, a strict first-come, first-serve priority must be used to arbitrate between activity arriving in sequence on different ports.

An N-port active hub employs a finite state machine with N+1 states. One of these states is an idle state, where the receivers are enabled on all ports and the transmitters are disabled on all ports. As soon as activity is detected on any port, a transition is made to one of the other N states, based upon the port from which activity was first detected. The resulting state is a state in which the receiver of the port from which the activity was detected remains enabled, while the receivers of all other ports are disabled; and with transmitters enabled on all ports other than the port from which the activity was detected. Once this active state is entered, all signals received on the (enabled) receive port are re-transmitted, approximately simultaneously, on all other ports.

Note that in the ordinary circumstance, this regeneration of the signals does not involve re-timing of the signals. Therefore, bit jitter accumulates from hub to hub, thereby limiting the number of hubs which may be used on any path between stations.

Once any particular active state has been entered, the hub remains in that state until a predefined time-out period, the hub unlatch delay (THU) has elapsed with no receive activity detected. Upon THU time-out, the hub returns to the idle state. The duration of THU provides for cancelling of echoes from unterminated cables.

This is accomplished because THU is longer than the worst case, round-trip delay to the far end of a maximum length cable. This prevents echoes from the far end of a cables from being mistakenly interpreted as incoming activity. THU is shorter than the

7.5.2 Unshielded Twisted Pair Cable

The MIC for use with unshielded twisted pair cable (telephone cable) is a conventional RJ11-C.

Sample part numbers:
AMP 520250-2

8.4 Hub Timing

8.4.1 Unlatch Delay

The hub unlatch delay, THU, must be between 5.0us and 12.0us. However, it is highly recommended that the time be set with a minimum of 5.2us and a maximum of 7.8us.

8.4.2 Bit Jitter

When regenerating the waveform it is necessary that the timing of all the signals within any given ISU not vary from the proper position, relative to the first bit of the ISU (or from each other), by more that 2.5ns. This permits the use of up to 10 active hubs in the path between any pair of stations without degradation of the bit error rate. Hubs with greater than this amount of bit jitter may be used if this fact is documented and the permissible number of hubs per path are appropriately reduced. However, "ARCNET/S" compatibility requires that the full 10-hub limit be met.

8.4.3 Throughput Delay

The delay from receiving a signal on the active input port to re-transmitting that signal on all other ports m .st not exceed 700ns to permit the use of up to 10 hubs in the path between an pair of stations. Hubs with larger through delays may be used if this fact is documented, and the number of hubs per path are appropriately reduced. However, "ARCNET/S" compatibility requires that the full 10-hub limit be met.

minimum interframe gap, so as to always return the hub to the idle state prior to the beginning of the next frame.

The diagram below shows a typical finite state machine for an active hub.

A legen of FSM notation appears in section 1.3.

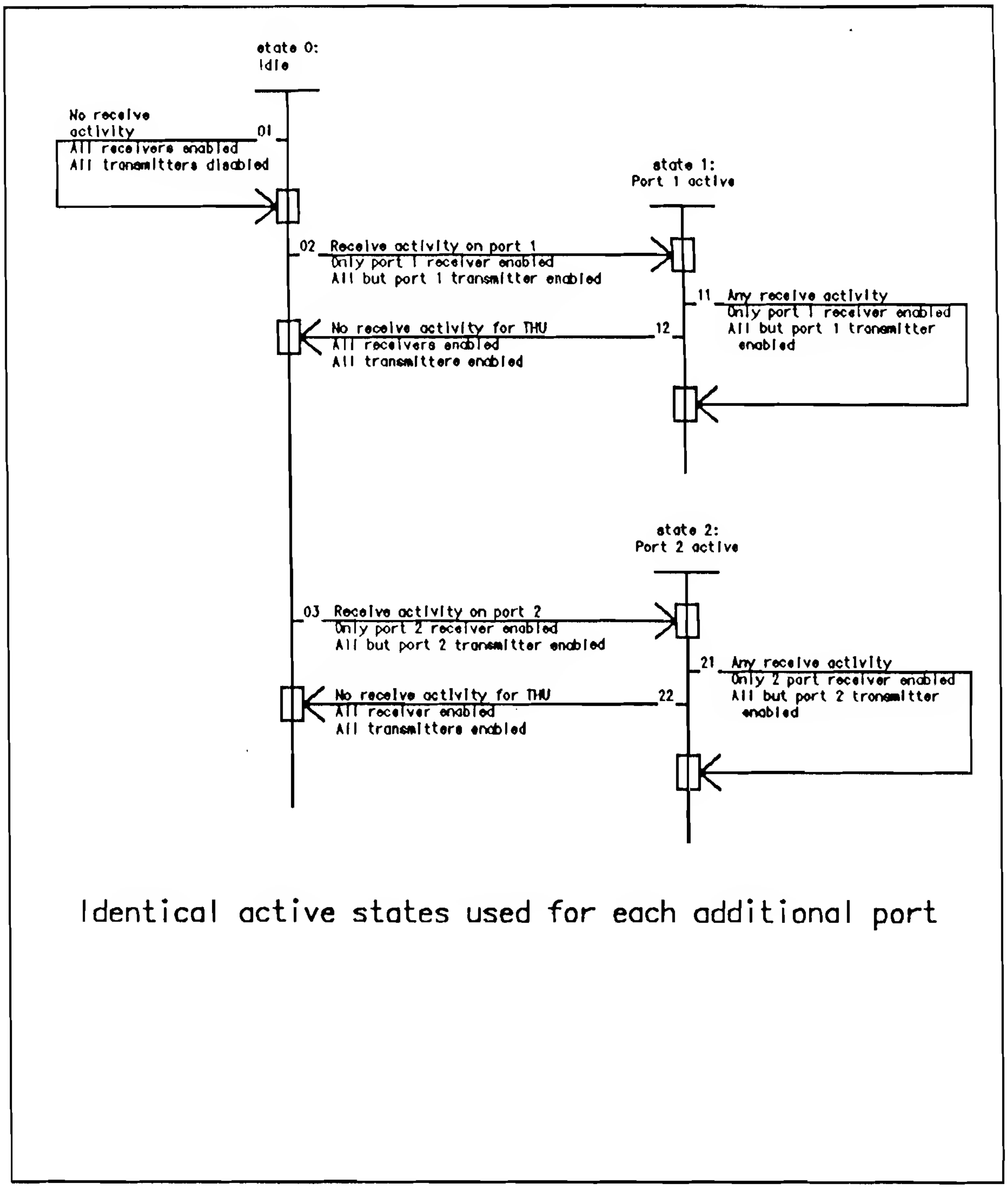


Figure 8.1 - Hub Finite State Machine

Decimal	Octal	Hex	Company
211	323	D3	PUREDATA, I-NET
212	324	D4	Novell, DOD Internet Protocol RFC
213	325	D5	Novell, Address Resolution Protocol RFC
214	326	D6	Novell, Reverse Address Resolution Protocol, RFC
215	327	D7	Giddings & Lewis Inc.
216	330	D8	Turnbull Control Systems, Ltd.
217	331	D9	Radiant Systems Inc.
218	332	DA	Opto 22 Corp.
219	333	DB	Network Interface Corp.
220	334	DC	Quantum Software Systems Ltd.
221	335	DD	Apple Corp. (AppleTalk)
222	336	DE	Systech Computer Corp.
223	337	DF	Johnson Controls
224	340	E0	Corvus
225	341	E1	Anasys
226	342	E2	ATA, Address Resolution Protocol
227	343	E3	Quantel
228	344	E4	Standard Microsystems Corp.
229	345	E5	Barrister Info. Systems, Inc.
230	346	E6	ICONICS
231	347	E7	COMENDEC -- Control Expo '88, file transfer
232	350	E8	Cogent Data Technology
233	351	E9	Contemporary Control Systems, Inc.
234	352	EA	Andover Controls
235	353	EB	MagneTek Louis Allis
236	354	EC	Standard Microsystems Corp.
237	355	ED	Standard Microsystems Corp.
238	356	EE	Wicat Systems
239	357	EF	Charles River -- Universe Net
240	360	F0	Waterloo Microsystems -- Waterloo Port
241	361	F1	TCP/IP
242	362	F2	TCP/IP -- Address Resolution Protocol
243	363	F3	Performance Technology -- POWERlan
244	364	F4	TIAC Manufacturing -- NETBIOS
245	365	F5	COMENDEC -- Cimnet
246	366	F6	Net Designs -- AppleTalk
247	367	F7	Banyan Systems -- Vines
248	370	F8	Rolm Data
249	371	F9	Zenith Data Systems
250	372	FA	Novell Systems -- Netware
251	373	FB	General Automation
252	374	FC	Hazeltine
253	375	FD	Digital Research
254	376	FE	Nestar Systems
255	377	FF	Bank of Brussels Lambert (BBL)

2. Two-Byte System Codes

Hex	Company	Usage
0000-7FFF	invalid	MSB is one-byte code
8000-80FF	all	Diagnostic (ignore packet)
8100-81FF	all	Enhanced ARCNET MAC & NMT
8200-BFFF	not assigned	
C000-FFFF	invalid	MSB is one-byte code

9. System Code Assignments

The system code identifies the usage, and by implication the format, of the INFO field of data packet frames. Unambiguous system codes must be used in order to permit multiple high-level protocols to be used concurrently on a single ARCNET. To prevent conflicting system code assignments, system code values are assigned by the ARCNET Standards Committee upon request. Since system codes are a scarce resource, care should be taken to request a new system code only when the protocol requirement cannot be met using one of the assigned codes.

The conventional system code is a one-byte value, permitting 256 unique codes. 61 of these codes have been assigned as of 11/12/90. To provide an adequate supply of system codes for the foreseeable future, a two-byte format has been defined, using 62 of the remaining 195 one-byte values as escape codes. This leaves 133 unassigned one-byte codes, plus 15872 unassigned two-byte codes.

1. One-Byte System Codes

Decimal	Octal	Hex	Company	USAGE
0	000	00	Datapoint	Initial bootstrap request
1	001	01	Datapoint	DOS
2	002	02	Datapoint	reserved (fido)
3	003	03	Datapoint	RMS down line load
4	004	04	Datapoint	RMS non-repeated message
5	005	05	Datapoint	RMS repeated message
6	006	06	Datapoint	Spectrum private message
7	007	07	Datapoint	reserved (ISX)
8	010	08	Datapoint	9660
9	011	09	Datapoint	Intelligent Hub
10	012	0A	Datapoint	reserved (ISX)
11	013	0B	Datapoint	1550 DOS
12	014	0C	Datapoint	reserved (CP/M)
13	015	0D	Datapoint	Test output
14	016	0E	Datapoint	RASL
15	017	0F	Datapoint	MINX
16	020	10	Datapoint	UNOS -- 32ATTACH
17	021	11	Datapoint	VCS
18	022	12	Datapoint	Multiterm
19	023	13	Datapoint	GS90
20-127	024-177	14-7F	not assigned	
128	200	80	all	Diagnostic (ignore packet)
129	201	81	all	Enhanced ARCNET MAC & NMT
130-191	202-277	82-BF		used in two-byte system codes
192-210	300-322	C0-D2		not assigned